RSAC 2025 Conference

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One Community.

SESSION ID: TPV-T01

Mapping CI Interdependence: Cyber Connectivity and Supply Chain Metrics

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Open Science @ Carleton University, Ontario

The mission of the **National Centre for Critical Infrastructure Protection, Security and Resilience (NC-CIPSeR)** is to develop and conduct multidisciplinary research in critical infrastructure protection with the goal of enhancing the safety and security of the Canadian population.

Open Science

The research prioritizes open science by sharing methodologies, data, and results widely.

https://carleton.ca/cipser

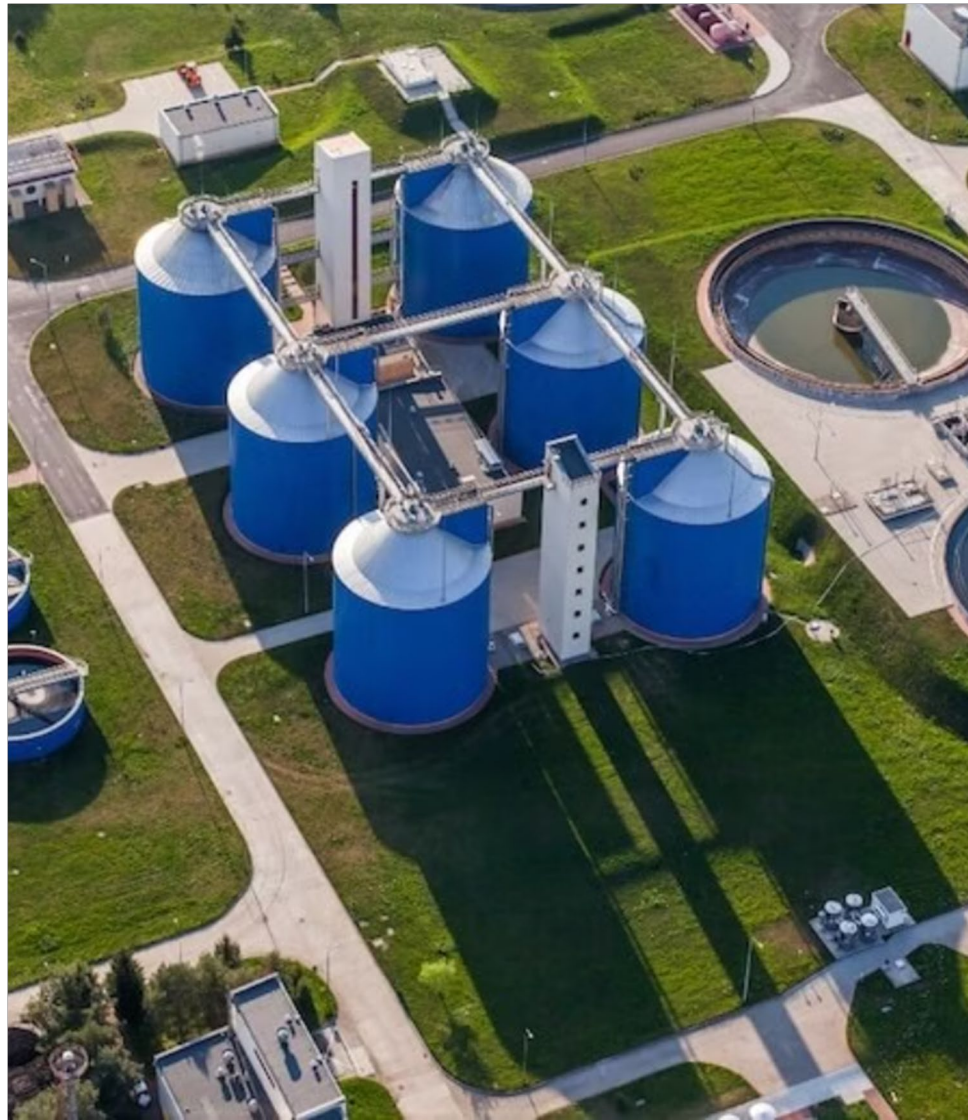
Defining Critical Infrastructure (CI)

The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society.

United Nations Office for Disaster Risk Reduction (UNDRR). 2017. The Sendai Framework Terminology on Disaster Risk Reduction. "Critical infrastructure". https://www.undrr.org/terminology/critical-infrastructure.

Or,

Critical infrastructure encompasses essential goods and services that underpin the safety, security and prosperity of modern society.



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What are Critical Infrastructure Sectors?

- Energy
- Communications and IT
- Finance
- Healthcare
- Food
- Water
- Transportation
- Safety
- Government
- Manufacturing

- Energy
- Dams
- InfoTech
- Communications
- Finance
- Healthcare and Public Health
- Food and Agriculture
- Water
- Transportation
- Safety
- Government
- Chemical
- Critical Manufacturing
- Defense Industrial Base
- Nuclear
- **Commercial Facilities**

- Communications
- **Data storage or processing**
- Defense
- Energy
- Financial services and markets
- Food and grocery
- Health care and medical
- Space technology
- Transport
- Water and sewerage
- **Education and research**

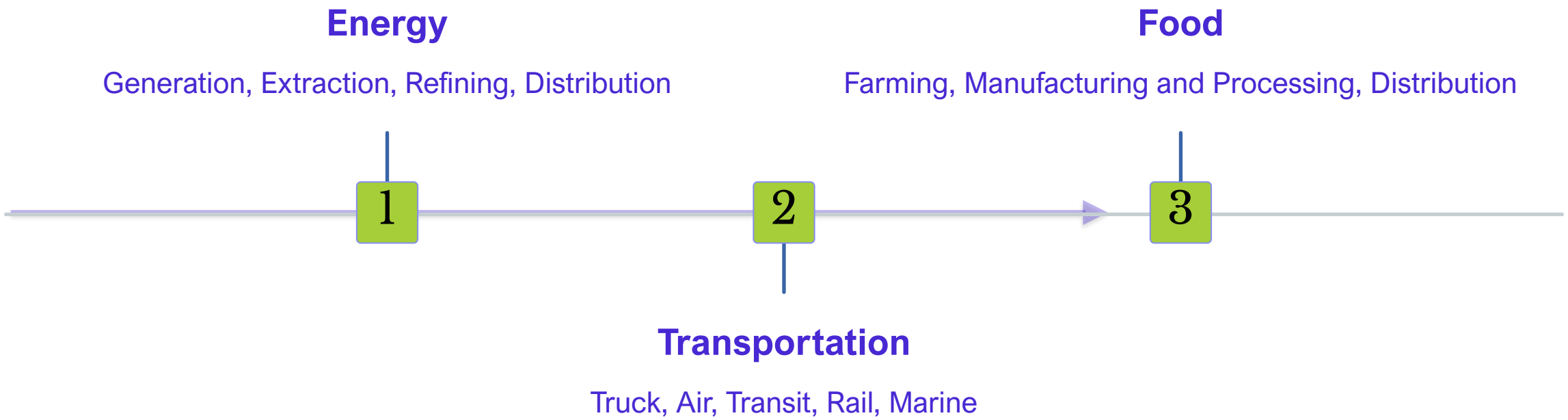
What is Critical Infrastructure Interdependence?

Critical infrastructure interdependence (CCI) refers to the reliance of different infrastructures **on each other**.

When one system experiences a disruption, it can trigger cascading supply-chain effects across other sectors and industries.

“Final Consumption” or “End Use” is not included in this research.

Example of CII: “Energy cascade”



Why Understand CI Interdependency (CII)?

Risk Management

Critical infrastructure interdependency is complex. Effectively managing and mitigating risk requires more than just intuition. Using metrics and data-driven approaches provides a structured and reliable framework for understanding and managing risk.

Blind Spots

Lack of understanding about interdependency often leads to poorly understood risks. Metrics and visualizations facilitates informed decision-making.

Planning and Exercising

Understanding interdependency is crucial to many stakeholders: policy makers, regulators, emergency managers, risk managers, insurers, and exercisers can identify potential vulnerabilities and develop appropriate strategies.

Common CI Risk Assessment Gaps

Definitions

Critical infrastructure definitions vary widely, leading to confusion and hindering effective risk management.

Missing sectors

Existing definitions are often OLD or based on intuition and may not include emerging critical industries.

Limited Sector engagement

There's limited engagement with industry sectors when defining and implementing critical infrastructure policies and regulations.

Metrics

A lack of consistent and comprehensive metrics makes it difficult to formulate and substantiate risk management decisions.

Using CII Metrics in Practice

CII metrics help assess the impact of disruptions on critical infrastructure.

These measures provide insights into interconnectedness and interdependencies among critical infrastructure industries.

Example: Interdependencies between Energy and Finance on scale out of 10

USE/MAKE	Energy	Finance
Energy	9	8
Finance	6	9

Compound Metrics – Why and What?

- No single metric adequately measures interdependence across critical infrastructure sectors.
- Multiple complementary metrics provide a more comprehensive assessment of vulnerabilities and resilience.
- Look for key "indicators" that reveal relationships between sectors:
  - Cyber metrics = data and communication sensitivities
  - Supply chain dependencies

These compound metrics help policymakers and operators identify critical nodes where targeted interventions would have the greatest protective impact.

Cyber Metric Survey

Survey Scope

Data sensitivity within critical infrastructure sectors.

Normal operating conditions.

Design

Three questions.

Cyber sensitivity.

Scale: 1 (lowest) to 10.

Respondents

Security Executives

IT Executives

Canadian Industries

Confidentiality

10. How sensitive to **confidentiality** (unauthorized or untimely disclosure) is the information received from other CI sectors under normal conditions?

	Not Important	Very Minimal	Minimal	Somewhat Unimportant	Moderate	Important	Very Important	Extremely	Paramount	Critical
Energy	○	○	○	○	○	○	○	○	○	○
Finance	○	○	○	○	○	○	○	○	○	○
Food	○	○	○	○	○	○	○	○	○	○
Transportation	○	○	○	○	○	○	○	○	○	○
Government	○	○	○	○	○	○	○	○	○	○
Information and Communication Technology	○	○	○	○	○	○	○	○	○	○
Health	○	○	○	○	○	○	○	○	○	○
Water	○	○	○	○	○	○	○	○	○	○
Safety	○	○	○	○	○	○	○	○	○	○
Manufacturing	○	○	○	○	○	○	○	○	○	○

Integrity

8. How sensitive to **Integrity** (corruption and/or unauthorized changes) is the information you receive from other CI sectors, under normal conditions?

	Not Important	Very Minimally	Minimally	Somewhat Unimportant	Moderately	Important	Very Important	Extremely	Paramount	Critical
Energy	○	○	○	○	○	○	○	○	○	○
Finance	○	○	○	○	○	○	○	○	○	○
Food	○	○	○	○	○	○	○	○	○	○
Transportation	○	○	○	○	○	○	○	○	○	○
Government	○	○	○	○	○	○	○	○	○	○
Information and Communication Technology	○	○	○	○	○	○	○	○	○	○
Health	○	○	○	○	○	○	○	○	○	○
Water	○	○	○	○	○	○	○	○	○	○
Safety	○	○	○	○	○	○	○	○	○	○
Manufacturing	○	○	○	○	○	○	○	○	○	○

Availability

6. How important is the **availability** (timely delivery and/or unauthorized deletion) of data received from the following critical infrastructure sectors? (Sector Definitions.)

	Not Important	Very Minimal	Minimal	Somewhat unimportant	Moderately Important	Important	Very Important	Extremely Important	Paramount Importance	Absolutely critical
Energy	○	○	○	○	○	○	○	○	○	○
Finance	○	○	○	○	○	○	○	○	○	○
Food	○	○	○	○	○	○	○	○	○	○
Transportation	○	○	○	○	○	○	○	○	○	○
Government	○	○	○	○	○	○	○	○	○	○
Information and Communication Technology	○	○	○	○	○	○	○	○	○	○
Health	○	○	○	○	○	○	○	○	○	○
Water	○	○	○	○	○	○	○	○	○	○
Safety	○	○	○	○	○	○	○	○	○	○
Manufacturing	○	○	○	○	○	○	○	○	○	○

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3	BS111CL0	Cannabis production (licensed)	44,614	2,282	165,347	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	BS111CU0	Cannabis production (unlicensed)	.	.	137,128	.	.	.	.	.	.	.	.	.	.	.	.	.	.
5	BS112A00	Animal production (except aquaculture)	709,213	277	180	.	4,005,585	45,456	3,029	2,017	51	738	1,532	1,172	137	43	312	320	6
6	BS112500	Aquaculture	13	3	1	.	12,955	22,299	35	3,426	3	3	316	206	51	.	69	40	1
7	BS113000	Forestry and logging	603	1,225	24	.	282	43	231,385	75	46	109	2,426	1,656	254	77	583	323	16
8	BS114000	Fishing, hunting and trapping	.	.	.	.	.	53,887	.	8,407	.	.	.	.	.	.	.	.	.
9	BS115A00	Support activities for crop and animal product	1,001,687	51,243	25,327	.	718,986	19,110	.	.	.	.	.	2	.	.	2	.	.
10	BS115300	Support activities for forestry	.	.	.	.	.	.	1,897,339	.	.	31,383	.	.	.	.	.	.	.
11	BS211110	Oil and gas extraction (except oil sands)	129,723	169,010	56,656	.	141,607	10,130	17,255	711	6,804	3,505	1,662,320	3,019,855	48,508	181	65,658	43,747	21,85
12	BS211140	Oil sands extraction	1,619	413	179	2,328	1,565	119	1,852	40	367	211	36,521	485,105	6,320	1,937	8,638	5,635	2,05
13	BS212100	Coal mining	1	.	.	.	.	.	2	.	.	.	31	20	5	.	7	4	
14	BS212210	Iron ore mining	68	8	12	.	33	3	13	2	.	13	67	48	.	102,772	20	4	
15	BS212220	Gold and silver ore mining	489	61	1	6	215	72	1,293	29	246	158	26,204	17,034	4,401	21	6,323	3,403	1,49
16	BS212230	Copper, nickel, lead and zinc ore mining	1,819	229	77	.	863	154	2,076	77	347	431	38,395	24,754	6,304	100	9,111	4,902	2,56
17	BS212290	Other metal ore mining	103	13	.	.	45	15	278	5	52	32	5,585	3,599	1,428	1,112	27,695	10,730	8,07
18	BS212310	Stone mining and quarrying	141	17	3	.	63	17	278	8	50	52	10,053	8,020	964	411	3,993	58,094	92
19	BS212320	Sand, gravel, clay, and ceramic and refractor	933	119	64	.	462	43	197	36	3	222	22,864	21,950	1,171	4,004	61,109	59,806	8,58
20	BS212392	Diamond mining	66	8	3	.	32	5	58	3	9	15	1,028	658	167	3	226	124	5
21	BS21239A	Other non-metallic mineral mining and quarry	24	3	.	.	10	3	62	51	12	9	84,967	115,989	1,978	261	5,163	14,259	1,32
22	BS212396	Potash mining	438,029	17	.	.	60	21	372	7	70	42	7,656	5,077	1,650	878	22,561	8,882	3,35
23	BS21311A	Support activities for oil and gas extraction	372	46	.	.	162	55	1,002	24	188	118	6,908,749	2,797,768	3,418	.	4,563	2,508	1,11
24	BS21311B	Support activities for mining	69	8	.	.	29	10	182	8	34	25	3,943	3,061	14,828	33,026	786,142	298,601	110,96

Econometric Methodology

Flow of Goods and Services in Economy

Input – Output / Supply – Use tables

Including Import / Exports = Cross-border dependencies

Open Source Statistics

Ex. Bureau of Economic Analysis, Stats Canada

Most OECD (Organisation for Economic Co-operation and Development) countries publish Input – Output tables.

Often 2 to 3 years in arrears.

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History of Risk Assessment with Econometrics

Source	Period	Summary
W. Leontief	1960's – 1990's	Developed Input-Output tables. Awarded Noble Prize 1973.
H. Kunreuther	1980's – 2000's	Developed and researched the relationship between industrial "Interdependent security" and I-O.
Y. Haimes	1990's – 2010's	Applied I-O Interoperability directly to risk management of specific CI Industries.
T. Macaulay	2000's - present	Developing an I-O matrix supporting all CI sectors and correlated with cyber security metrics.
European Commission	2010's	European risk assessment tools - FIDELIO
Defense Research and Development Canada (DRDC)	2021	National Critical Infrastructure Interdependency Model - NCIM
RAND Corporation	2000's - present	Developing I-O models to analyze the economic impacts of infrastructure failures

Energy Sector – Components Industries

Oil and Gas extraction

BS21100

Coal Mining

BS21210

Electricity generation, transmission and distribution

BS22110

Petroleum refining

BS32400

Pipeline Transportation

BS48600

Gas Stations / Charging Stations

BS44700

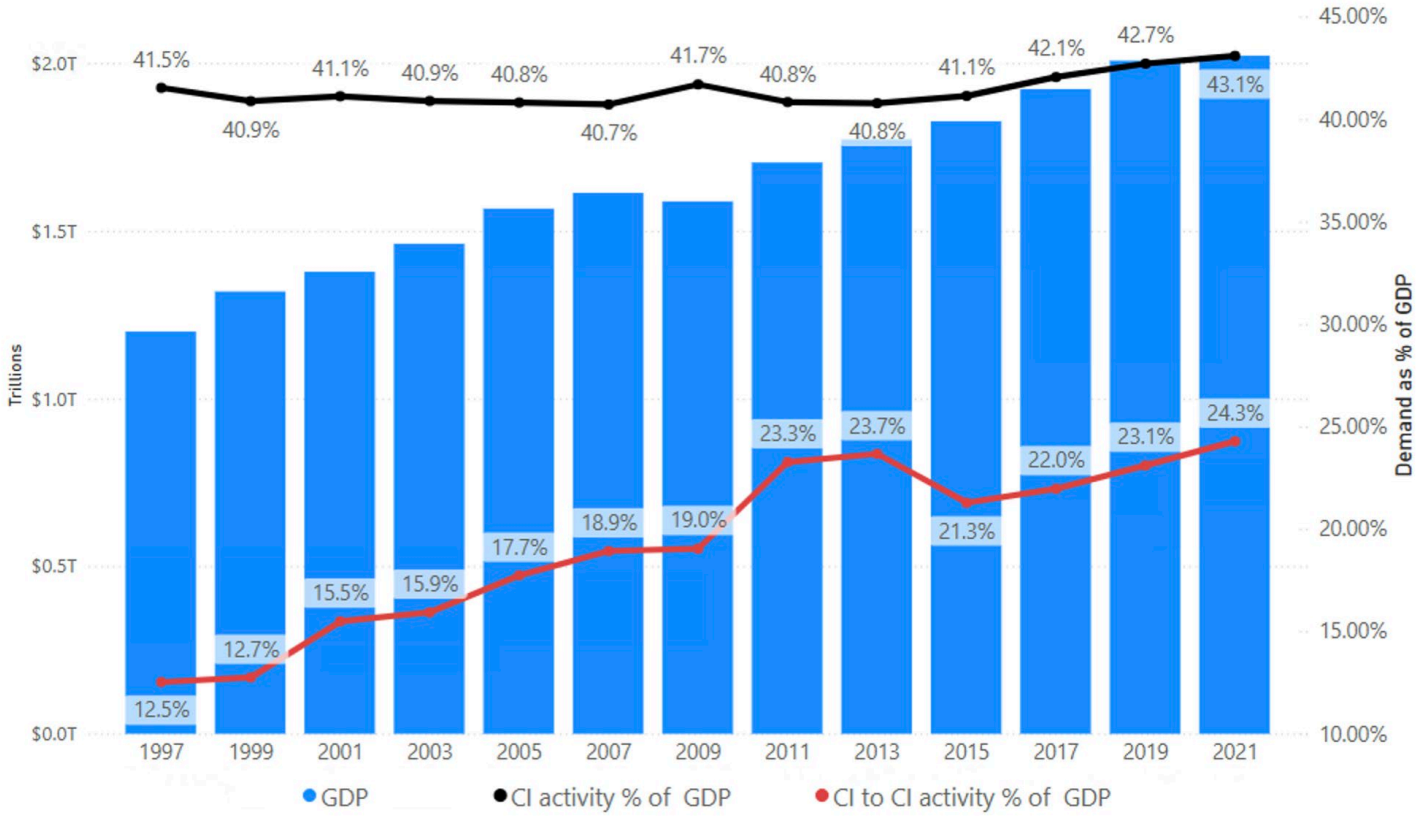
CI supply chain: 1997-2021

Black line: CI sector spending as percentage of GDP.

Red line: CI Intra-sector spending as percentage of GDP.

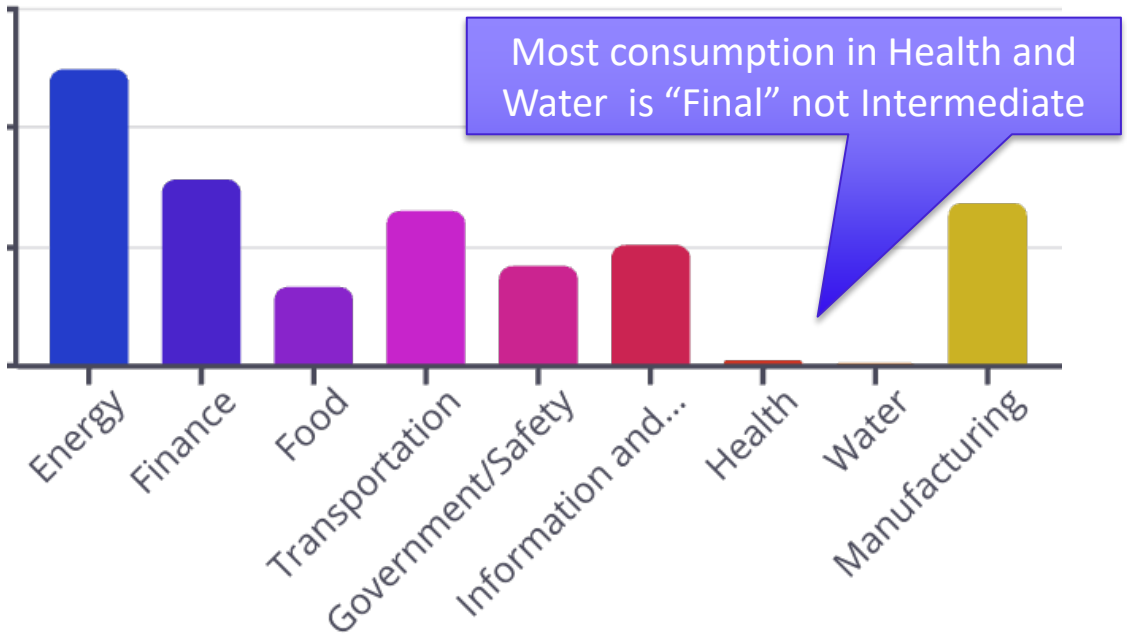
Observations: CI sectors are spending 80%+ more resources on each other now than 25 years ago.

Conclusion: CI Supply-chain interdependence has become more intense.

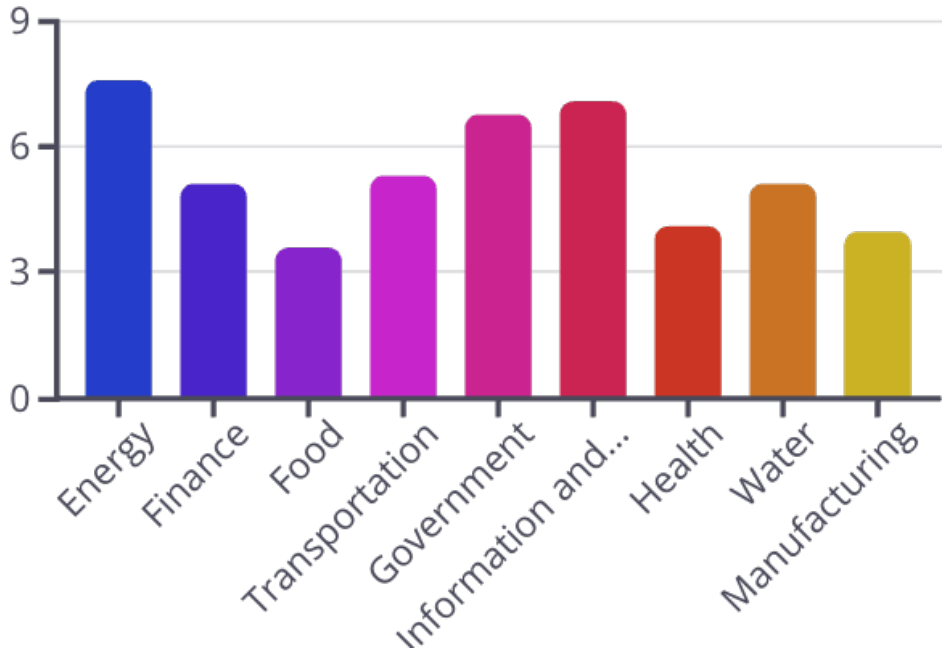


Energy: Spending versus Cyber Survey 2024

Spending in CI Supply Chain (Log Scale)



Cyber - Data Sensitivity (1 to 10 scale)



2024 Econometric to Cyber Correlation *0.65 (Moderate to Strong)*

2007 Correlation *0.77 (Strong)*

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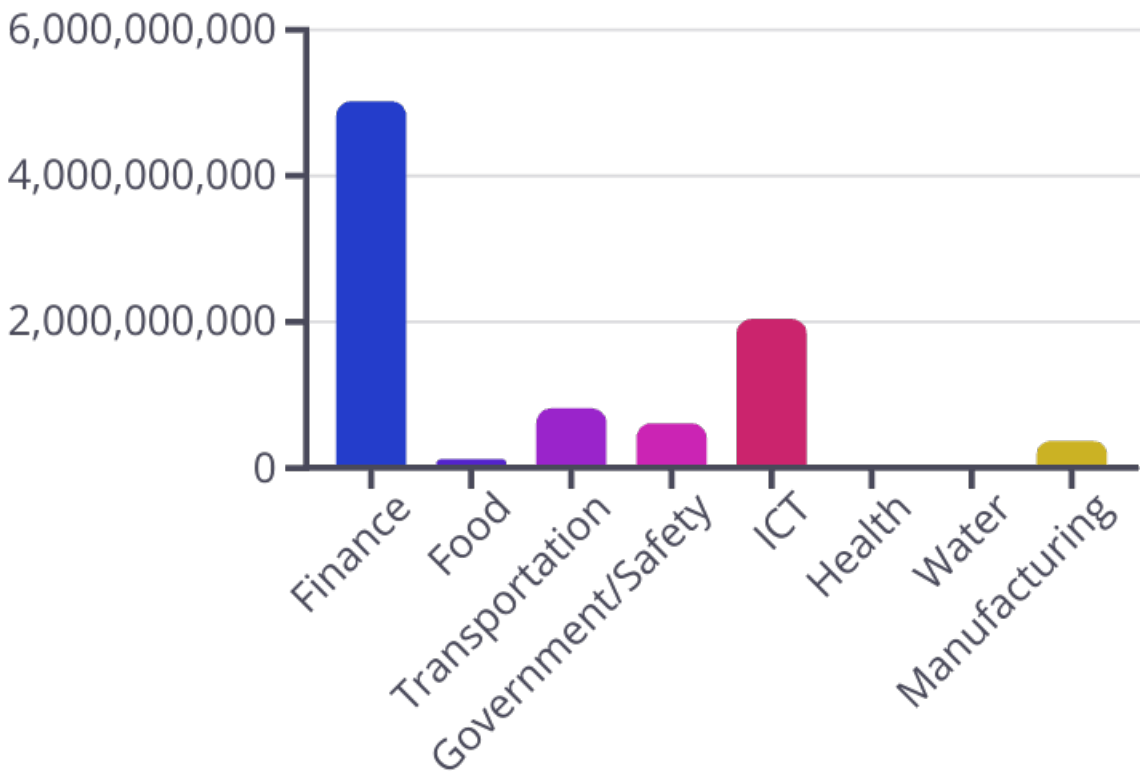
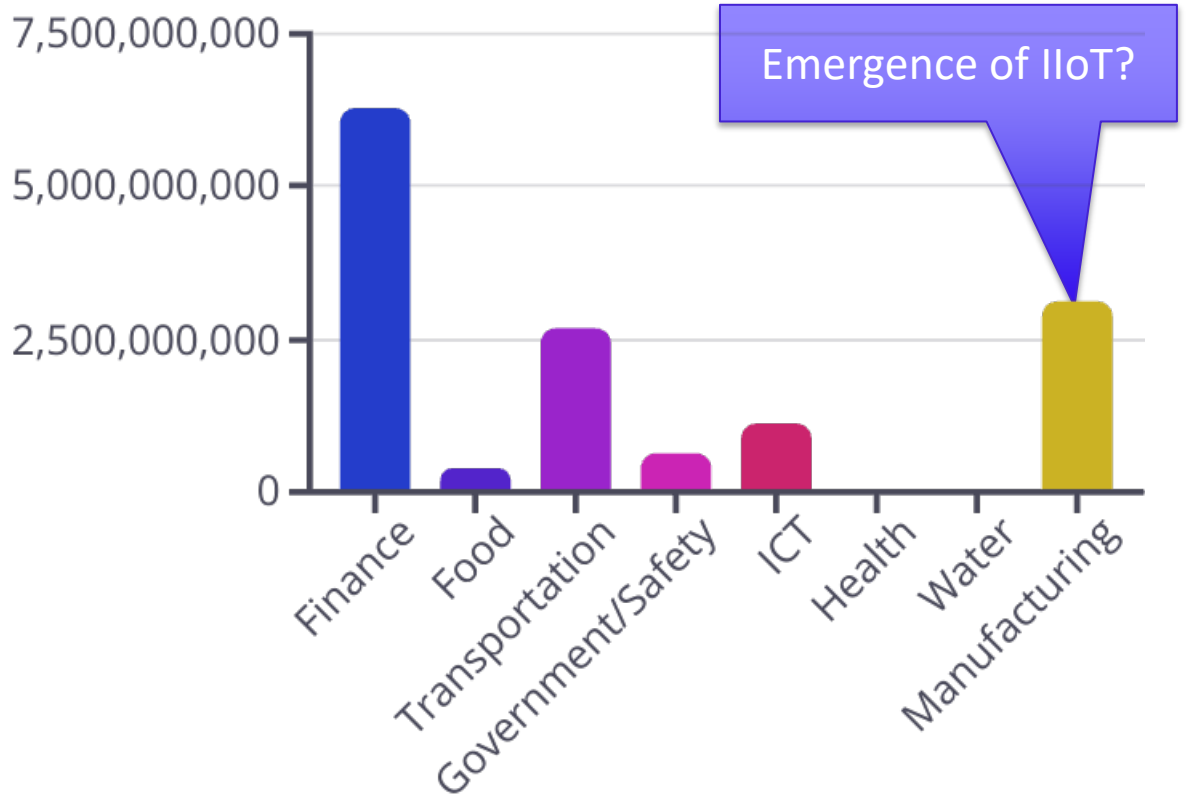
Energy: Supply Chain spending changes

2007 Spending on other CI sectors



2022 Spending on other CI sectors



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Case Study – March 2024

2 x Concurrent CI impacts

Many Voices.
One Community.

Manitoba CII Case Study – Spring 2024

Fuel Pipeline Shutdown

The only fuel pipeline from the US border to Manitoba experiences an emergency shutdown due to maintenance requirements.

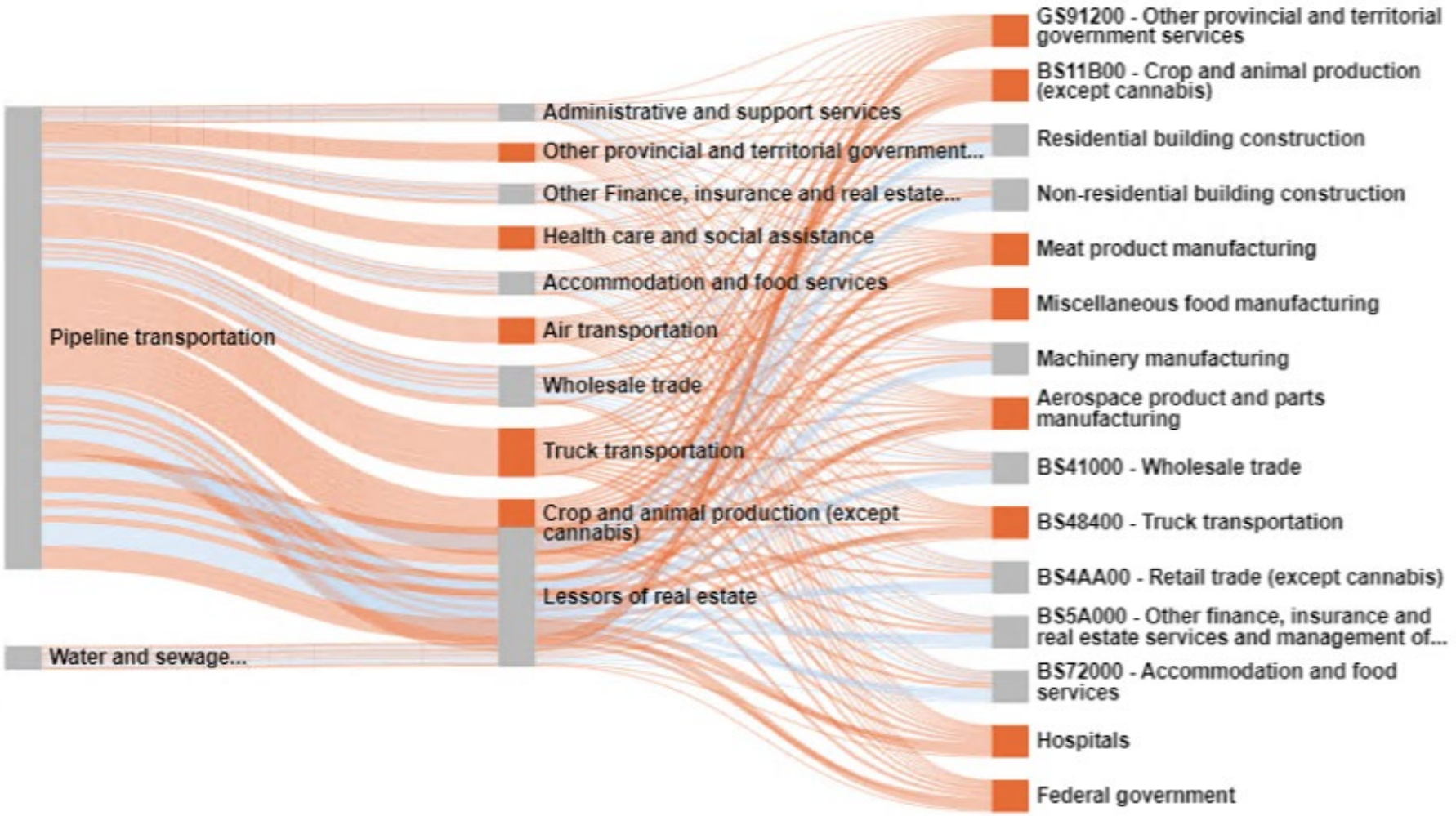
Wastewater Main Rupture

A major wastewater main in Winnipeg ruptures, releasing 4 billion liters of untreated water into the Assiniboine River.

Cascading Effects

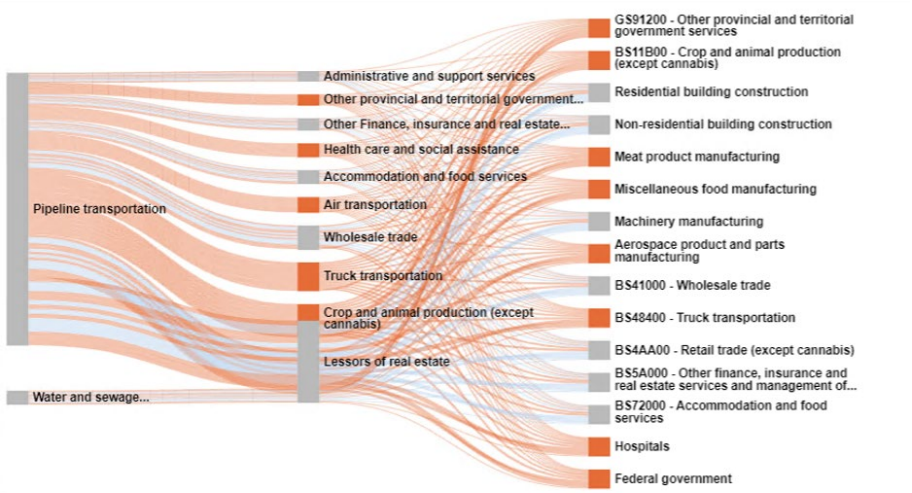
These disruptions have cascading effects across the province, affecting transportation, water quality, and public health.

Manitoba CII Case Study – Spring 2024


Pipeline transportation
Water and sewage...
Administrative and support services
Other provincial and territorial government...
Other Finance, insurance and real estate...
Health care and social assistance
Accommodation and food services
Air transportation
Wholesale trade
Truck transportation
Crop and animal production (except cannabis)
Lessors of real estate
GS91200 - Other provincial and territorial government services
BS11B00 - Crop and animal production (except cannabis)
Residential building construction
Non-residential building construction
Meat product manufacturing
Miscellaneous food manufacturing
Machinery manufacturing
Aerospace product and parts manufacturing
BS41000 - Wholesale trade
BS48400 - Truck transportation
BS4AA00 - Retail trade (except cannabis)
BS5A000 - Other finance, insurance and real estate services and management of...
BS72000 - Accommodation and food services
Hospitals
Federal government

Downstream cascading impacts from concurrent CI impacts: Pipeline (Energy) and Waste water (Water)

Accumulation of CI2CI cascading impacts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Federal government

Number of industries from a given CI sector impacted, at different levels:

- Primary = first impact
- Secondary = cascading impact

	Energy	Food	Finance	Manufacturing	Gov/Safety	Health	Telecoms	Transport	Water
Impacted CI	1								1
Primary		2			3	3		2	
Secondary		4		2	4	2		2	
Accumulated	1	6		2	7	5		4	1

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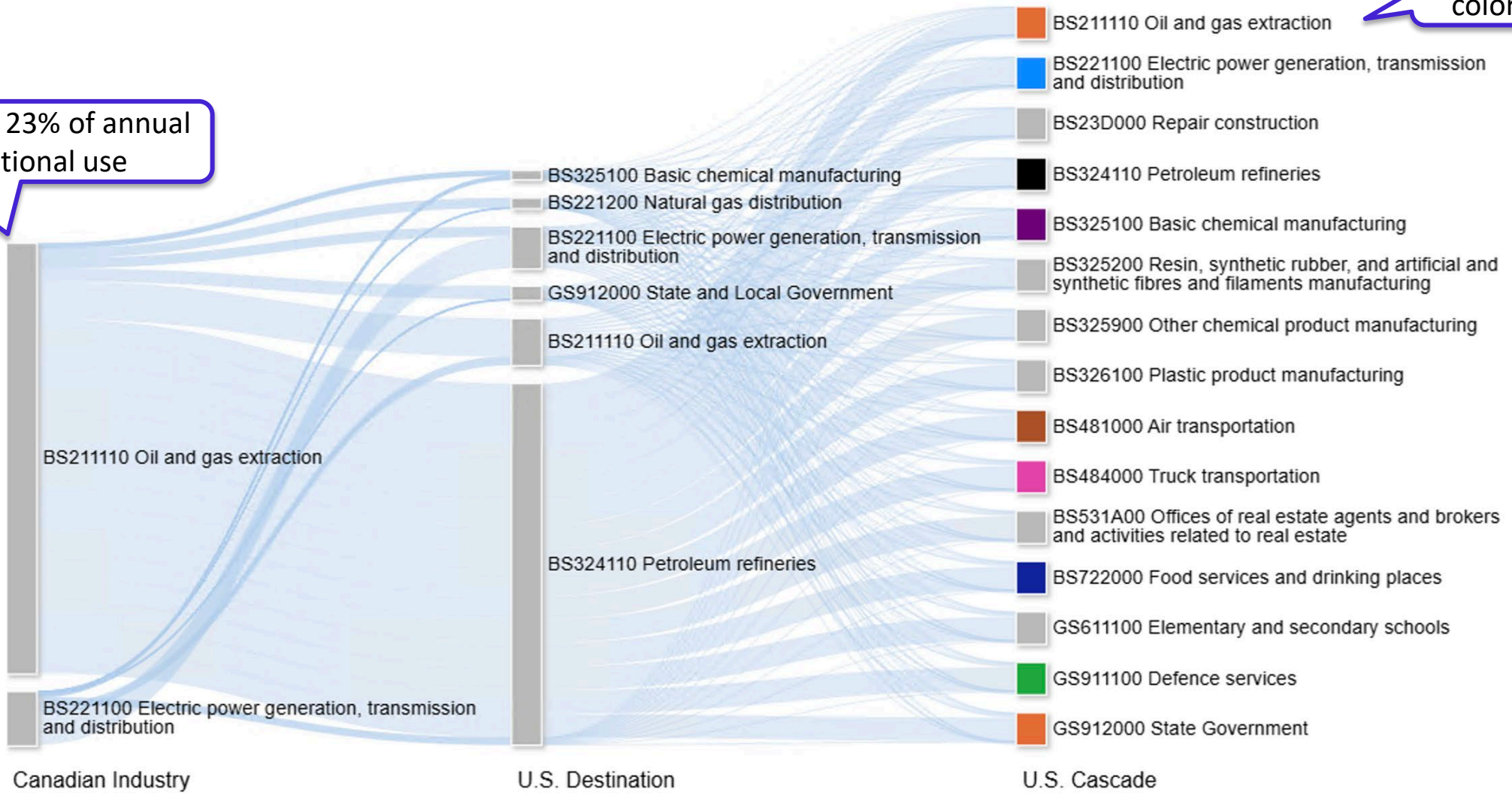
Cross-border dependencies

2022 Energy trade – Canada to U.S.

U.S. National Level

Approx 23% of annual national use

CI Industries in colored blocks

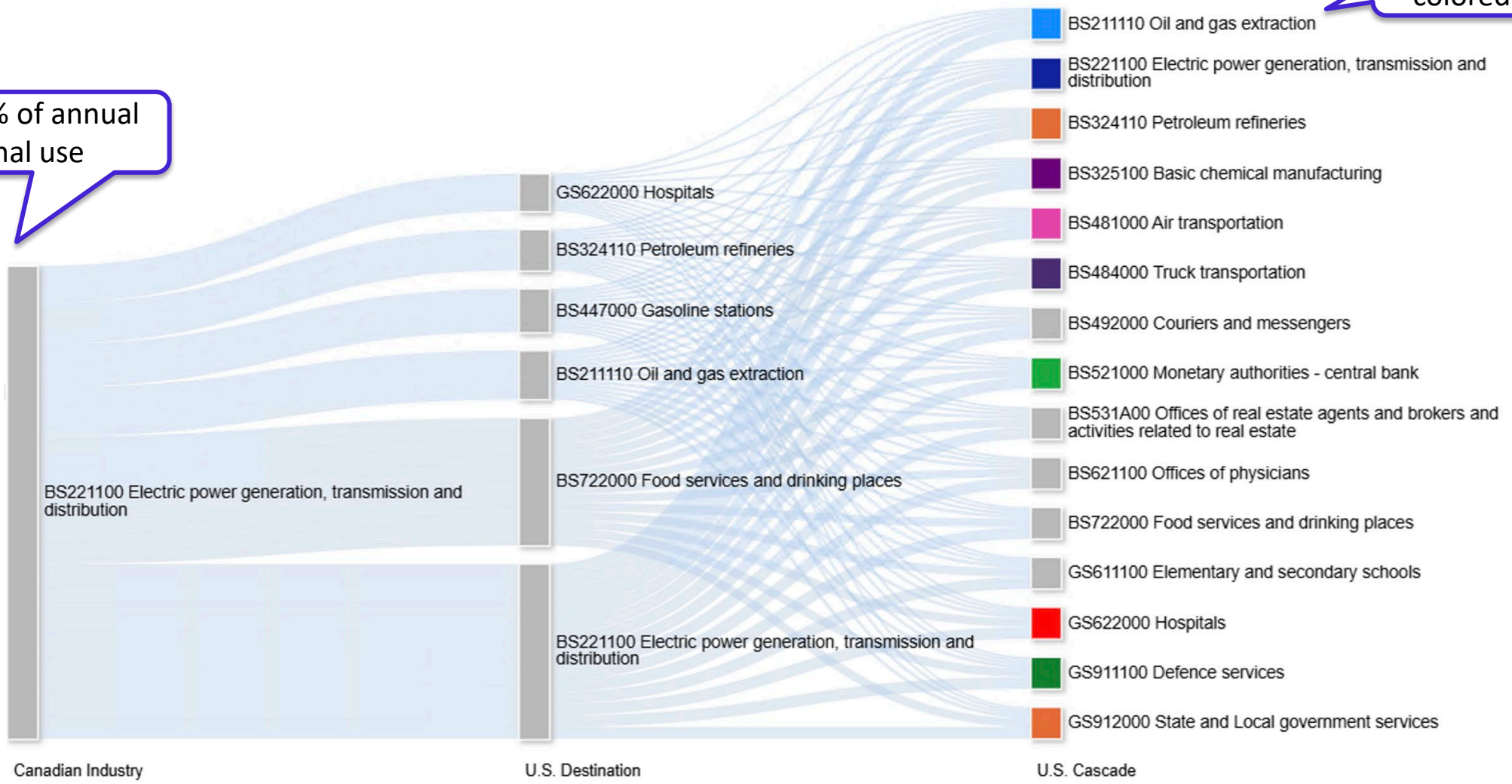

BS211110 Oil and gas extraction
BS221100 Electric power generation, transmission and distribution
BS325100 Basic chemical manufacturing
BS221200 Natural gas distribution
BS221100 Electric power generation, transmission and distribution
GS912000 State and Local Government
BS211110 Oil and gas extraction
BS324110 Petroleum refineries
BS211110 Oil and gas extraction
BS221100 Electric power generation, transmission and distribution
BS23D000 Repair construction
BS324110 Petroleum refineries
BS325100 Basic chemical manufacturing
BS325200 Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing
BS325900 Other chemical product manufacturing
BS326100 Plastic product manufacturing
BS481000 Air transportation
BS484000 Truck transportation
BS531A00 Offices of real estate agents and brokers and activities related to real estate
BS722000 Food services and drinking places
GS611100 Elementary and secondary schools
GS911100 Defence services
GS912000 State Government
Canadian Industry
U.S. Destination
U.S. Cascade

2022 Energy (Electricity only) – Canada to U.S.

U.S. National Level

CI Industries in colored blocks

Approx 2% of annual national use

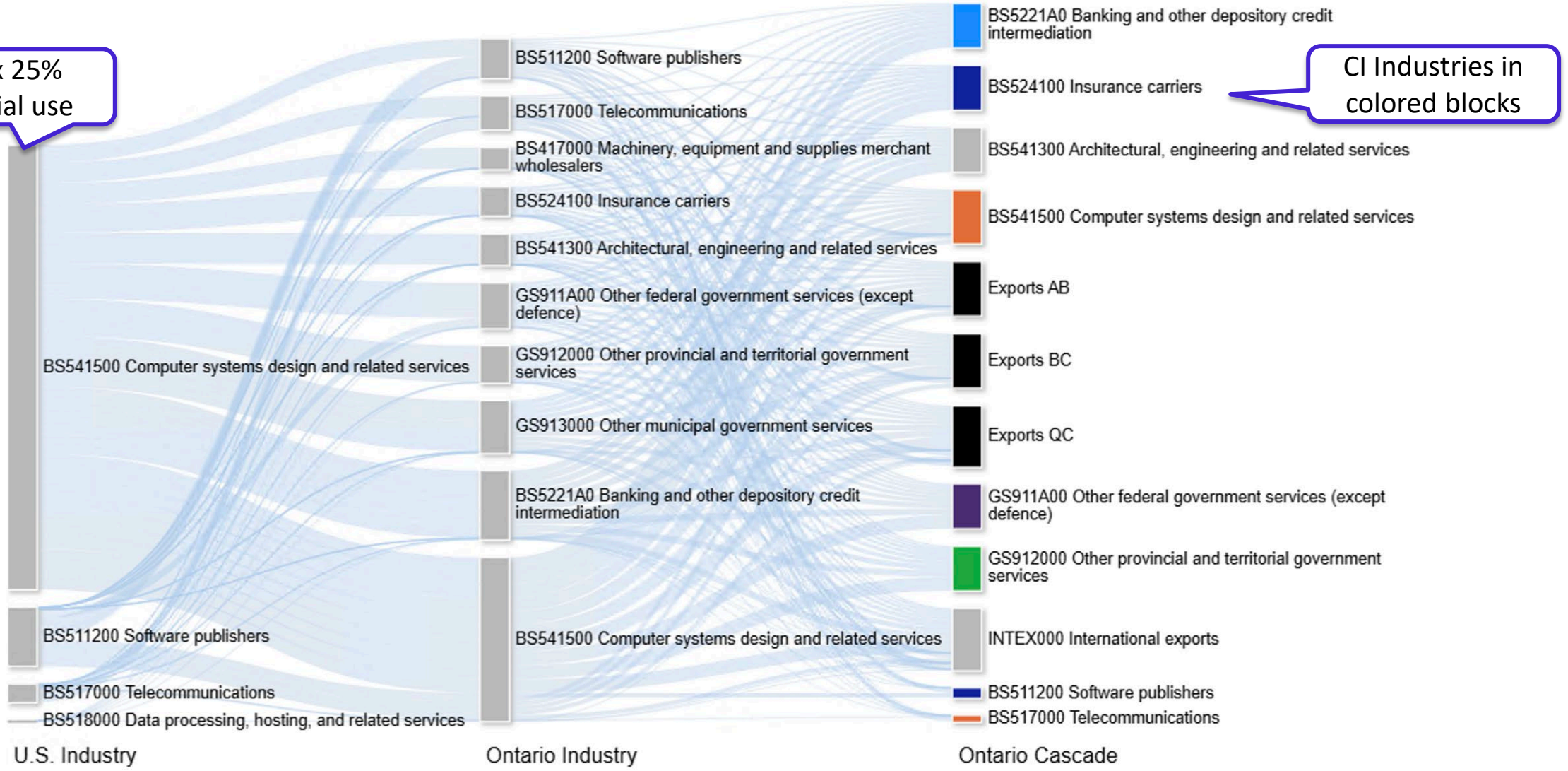

BS221100 Electric power generation, transmission and distribution
GS622000 Hospitals
BS324110 Petroleum refineries
BS447000 Gasoline stations
BS211110 Oil and gas extraction
BS722000 Food services and drinking places
BS221100 Electric power generation, transmission and distribution
BS211110 Oil and gas extraction
BS221100 Electric power generation, transmission and distribution
BS324110 Petroleum refineries
BS325100 Basic chemical manufacturing
BS481000 Air transportation
BS484000 Truck transportation
BS492000 Couriers and messengers
BS521000 Monetary authorities - central bank
BS531A00 Offices of real estate agents and brokers and activities related to real estate
BS621100 Offices of physicians
BS722000 Food services and drinking places
GS611100 Elementary and secondary schools
GS622000 Hospitals
GS911100 Defence services
GS912000 State and Local government services
Canadian Industry
U.S. Destination
U.S. Cascade

Communications Trade – U.S.A. to Ontario

Provincial level

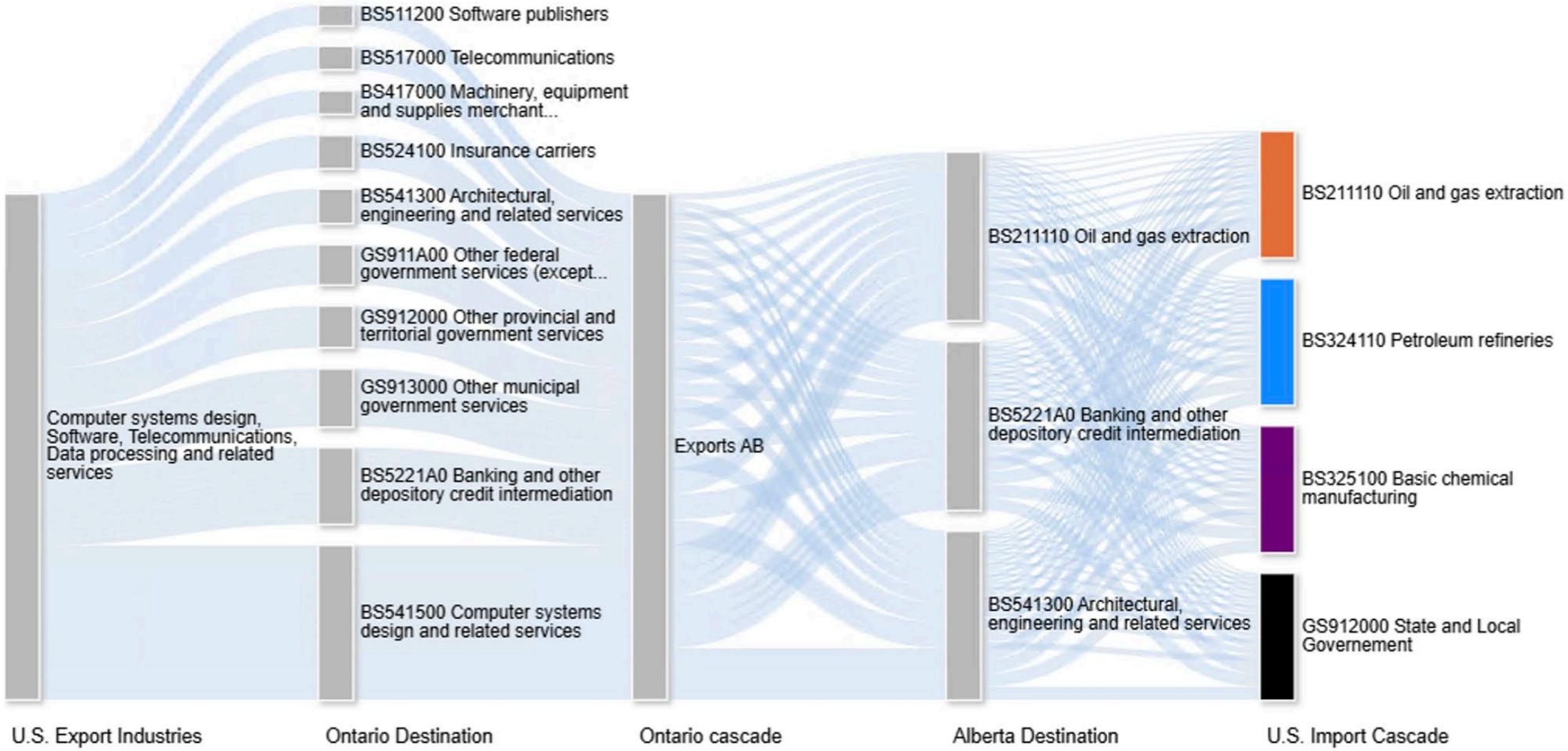
Approx 25% provincial use

CI Industries in colored blocks


BS541500 Computer systems design and related services
BS511200 Software publishers
BS517000 Telecommunications
BS518000 Data processing, hosting, and related services
U.S. Industry
BS511200 Software publishers
BS517000 Telecommunications
BS417000 Machinery, equipment and supplies merchant wholesalers
BS524100 Insurance carriers
BS541300 Architectural, engineering and related services
GS911A00 Other federal government services (except defence)
GS912000 Other provincial and territorial government services
GS913000 Other municipal government services
BS5221A0 Banking and other depository credit intermediation
BS541500 Computer systems design and related services
Ontario Industry
BS5221A0 Banking and other depository credit intermediation
BS524100 Insurance carriers
BS541300 Architectural, engineering and related services
BS541500 Computer systems design and related services
Exports AB
Exports BC
Exports QC
GS911A00 Other federal government services (except defence)
GS912000 Other provincial and territorial government services
INTEX000 International exports
BS511200 Software publishers
BS517000 Telecommunications
Ontario Cascade

XX Cascades – U.S. to Canada to U.S.A

U.S. National - Ontario – Alberta – U.S. National


BS511200 Software publishers
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BS417000 Machinery, equipment and supplies merchant...
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GS912000 Other provincial and territorial government services
GS913000 Other municipal government services
BS5221A0 Banking and other depository credit intermediation
BS541500 Computer systems design and related services
Computer systems design, Software, Telecommunications, Data processing and related services
Exports AB
BS211110 Oil and gas extraction
BS5221A0 Banking and other depository credit intermediation
BS541300 Architectural, engineering and related services
BS211110 Oil and gas extraction
BS324110 Petroleum refineries
BS325100 Basic chemical manufacturing
GS912000 State and Local Governement
U.S. Export Industries
Ontario Destination
Ontario cascade
Alberta Destination
U.S. Import Cascade

Apply what you learned here

- In the next month ask specific questions about your supply chain
  - Cyber sensitives of key suppliers AND customers
  - Spending and procurement – follow the money
- In the next 6 months
  - Understand how your business compares to National or Regional industrial metrics
  - Use cyber and spending metrics in risk assessments or exercises
- Within 6 months to a year you should:
  - Include the risks of cascading CI impact in your ERM models
  - Understand how your industry might trigger a cascade beyond your own customer-base

RSAC 2025 Conference

Many Voices.
One Community.

Thank you / Merci

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